Soybean & Wheat Response to Climate Change


PEGGY GREB (D1548-1)

Global greenhouse gas emissions are projected to rise dramatically in the next 40 years, with increased outputs of carbon dioxide (CO_2) being the main culprit. In light of our changing environment, Agricultural Research Service scientists in Urbana, Illinois, and Raleigh, North Carolina, are examining how the increase in greenhouse gases, particularly CO_2 and ozone, will affect two of the world's most widely planted crops: soybeans and wheat.

Open-Top Chambers Offer Insight

At the Plant Science Research Unit in Raleigh, ARS plant physiologists Fitzgerald Booker, Kent Burkey, and Ed Fiscus are assessing how climate change will affect soybean and wheat growth rates, crop yield, and soil chemistry by exposing the crops to the elevated levels of CO_2 and ozone projected for the year 2050.

Soybeans, wheat, and other crops grow more when CO_2 levels are elevated, because there is more carbon captured during photosynthesis for the plants to use. But those same plants are damaged and stunted by elevated levels of ground-level ozone, a gas created when sunlight "cooks" automotive and industrial pollutants that originate from combustion of carbon-based fuels.

Levels of both gases are rising. The Intergovernmental Panel on Climate Change, an international panel of highly regarded scientists, estimates that CO_2 levels could be about 1.5 times greater than the current 380 parts per million by 2050. The panel also estimates that daytime ozone in the summertime, now at about 50-55 parts per billion, may rise 20 percent over the same period.

INSTITUTE FOR GENOMIC BIOLOGY/UNIVERSITY OF ILLINOIS (D1546-2)

ARS scientists Carl Bernacchi (left), Don Ort (center), and Lisa Ainsworth in a plot of soybeans treated with elevated carbon dioxide (CO_2) at the SoyFACE Global Change Research Facility at the University of Illinois Research Farm in Urbana. In the foreground is an automatic retractable awning used to capture rainfall in order to investigate the interaction of drought and elevated CO_2 on soybean. Behind the scientists is an array of infrared heaters used to raise the temperature of a portion of the plot to investigate interactions with anticipated global warming.

Besides assessing the effects of future air concentrations on both crops, the researchers are conducting a 5-year project to determine whether a widely accepted no-till cropping system will improve soil quality and sequester carbon when levels of the gases rise.

"We know no-till increases carbon sequestration in the soil. The question is, What is going to happen with elevated levels of CO_2, and how are changes in other atmospheric gases, namely ozone, going to affect that?" Booker says.

The Raleigh researchers have 16 open-top chambers, divided into 4 treatments: 4 with elevated ozone, 4 with elevated CO_2, 4 with both gases elevated, and 4 controls. They are pumping the chamber air with up to 40 percent more ozone and CO_2 than what is found in today's ambient air. They are also charcoal-filtering the air so they can reduce ozone in the control chambers and tease out the impact that different ozone and CO_2 levels, by themselves, have on the plants.

In addition, the researchers are putting the postharvest residues, such as plant stems, empty pods, and dead leaves, back into the chambers, essentially

Plant physiologist Fitzgerald Booker prepares to place an optical scanner into a tube that will be positioned in the soil to photograph soybean roots. The photos will be analyzed to determine changes in root length and distribution caused by exposure to elevated carbon dioxide and ozone, which are pumped into the open-top field chambers.

making them small, self-contained plots that mimic conditions found in no-till systems. To measure changes in the soil's carbon and nitrogen content makeup, the researchers take samples twice a year. The CO_2 pumped into the chambers has a specific isotope marker so they can track it from the air through the plants and into the soil. They are analyzing the soil cores by depth to determine where composition changes may occur and also the amount of bacteria and fungi found in each layer to see whether microorganism populations or communities change.

After completing 3 years of the project, preliminary results show a trend for higher levels of soil carbon in chambers with elevated CO_2 but not in chambers with elevated ozone. Elevating CO_2 also reduced protein levels in wheat flour by 7 percent to 11 percent, but it had no effect on soybean seed protein.

SoyFACE: New Technology, New Understanding

Researchers in Urbana and cooperators with the University of Illinois at Urbana-Champaign have been working on a project called "SoyFACE"—short for Soybean Free Air Concentration Enrichment—that also measures how the projected increases in CO_2 and ozone will affect soybean production.

FACE technology, which was first used for crop research by ARS soil scientist Bruce Kimball, ARS plant physiologist Jack Mauney (now retired), and scientists from the U.S. Department of Energy's Brookhaven National Laboratory, allows testing of plants in open-air field conditions. ARS scientists Don Ort, Lisa Ainsworth, and Carl Bernacchi, in the Photosynthesis Research Unit, and Randall Nelson, in the Soybean/Maize Germplasm, Pathology, and Genetics Research Unit, use the technology to produce atmospheric conditions predicted for the year 2050.

Horizontal pipes arranged in an octagon about 70 feet in diameter surround each test plot. A computer measures wind direction and speed, then releases concentrated amounts of CO_2 and ozone. The wind carries the gases across the soybean crop.

"At the start of the project, we sought to understand how CO_2 and ozone affect soybean independently," says Ort. "We found soybean yield increases by about 12 percent at the elevated CO_2 concentrations predicted for 2050, half of what previous studies estimated. We also found that increased ozone is quite harmful to yield, reducing it by about 20 percent. In fact, our study showed current levels of ozone are already suppressing soybean yield by up to 15 percent."

The results of the individual studies led the scientists to examine the combined effects of CO_2 and ozone on soybean. They found that elevated CO_2 partially offsets the ozone damage. These findings with SoyFACE confirm general results obtained with open-top chamber studies of ozone and CO_2 effects on crop yield conducted at Raleigh and other locations. But the ability of SoyFACE technology to test these principles in the open air, without the environmental modifications caused by the chambers themselves, means greater confidence in our understanding of how plants respond in the real world, including the actual estimates of impact on crop yields. Furthermore, there is much to be learned about how other interacting factors that affect ozone uptake may come into play by mid-century.

The scientists recently began studying how combined factors will affect soybean production. They are looking at drought and increased temperature, drought and increased CO_2, and elevated temperature and CO_2. They'll also be analyzing how microbial communities and soil carbon storage are affected by these changes.

These projects provide valuable information that will help breeders develop soybean cultivars better adapted to an ever-changing climate.—By **Stephanie Yao** and **Dennis O'Brien,** ARS.

This research is part of Air Quality (#203), Global Change (#204), and Plant Biological and Molecular Processes (#302), three ARS national programs described on the World Wide Web at www.nps.ars.usda.gov.

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To assess oxidative stress in soybean grown at SoyFACE under elevated ozone concentrations, ARS molecular biologist Lisa Ainsworth (back) and graduate student Kelly Gillespie use a liquid-handling robot to perform a high-throughput assay.